INTER-OCEANIC SHIP CANAL ACROSS THE AMERICAN ISTHMUS.

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THE PROPOSED INTER-OCEANIC SHIP CANAL BETWEEN GREYTOWN AND BRITO, VIA LAKE NICARAGUA; ITS FEASIBILITY AS A COMMERCIAL QUESTION, AND ITS ADVANTAGES AS COMPARED WITH OTHER PROPOSED LINES.

[Read before the Society Nov. 12, 1878.]

Two years ago I had the honor to have read before this Society, by its Secretary, a Paper upon the sufficiency of the information relating to the topography of this continent, for the consideration and discussion of a trans-continental ship canal. The object was to set forth what was really known concerning the topography of the whole region which might be regarded as affording possible conditions for its construction.

Notwithstanding the laborious and creditable surveys made public before that time, and quoted to show the sufficiency of our information, it was believed by some learned men in Europe that the topography of certain portions of the territory had not been sufficiently developed. Under this belief, with praiseworthy action, they had set on foot a surveying party, well-equipped, under the command of Lieutenant WYSE, of the French navy, who was *en route* to make projected surveys over the region referred to, at the time of the reading of my paper.

Two seasons have been employed in the execution of these surveys, which have, without doubt, been ably made, and are reliable within the limits claimed by experts in such works; they are sufficient to form the basis of an instrumental location of the proposed work, and to permit an approximate calculation of the labor necessary, where construction is within the possibilities of the engineer. These surveys are, in this respect, useful, and especially for the consideration of those who thought the information presented two years ago was insufficient.

It is a fair presumption that the route over which an inter-oceanic

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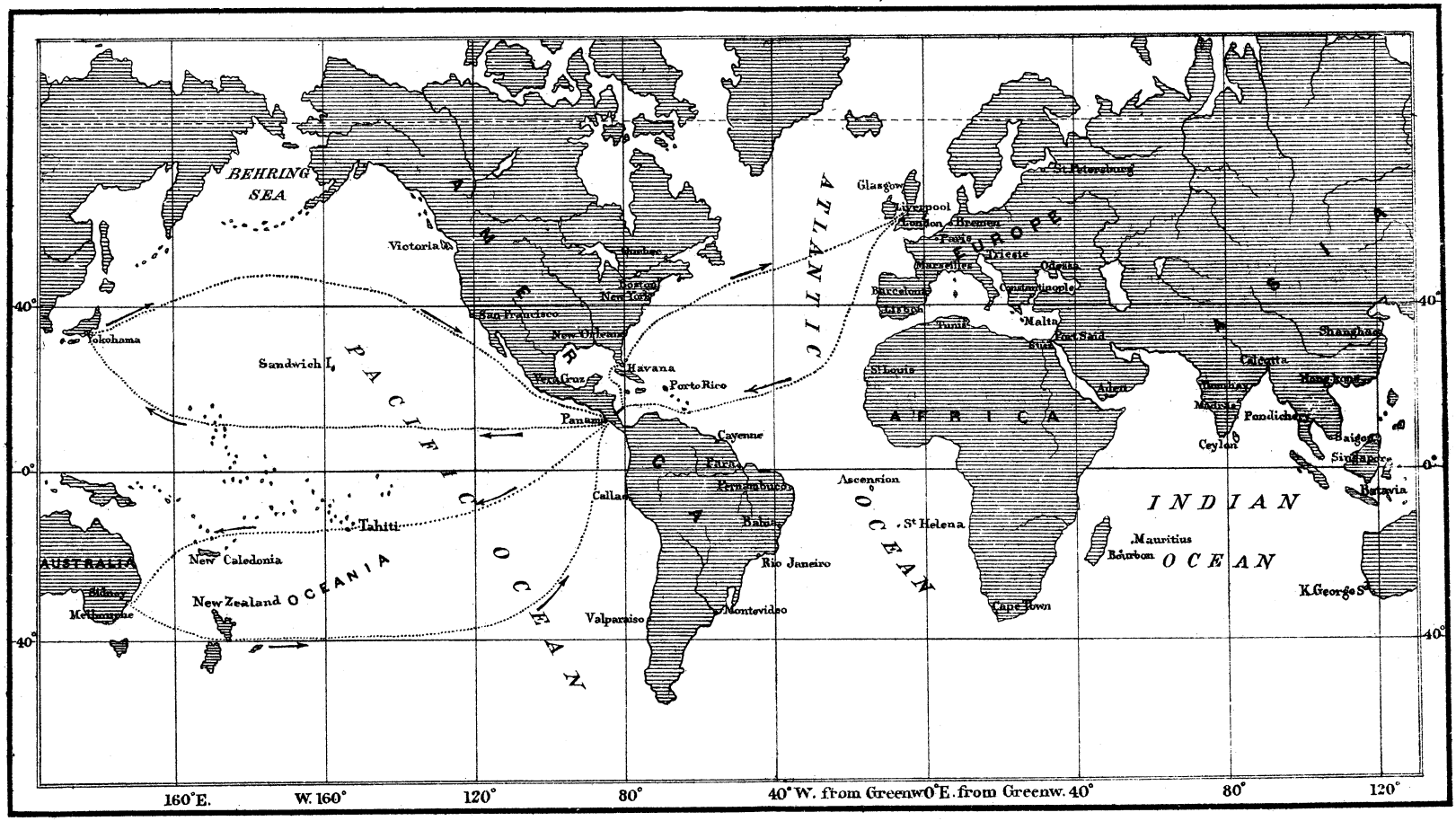
(Courses indicated by arrows.)



ship canal should be constructed, can only be named when it is shown that no better one exists. At this time the information is supposed to be all that can be desired by any one, relative to a fair consideration of the subject.

After an examination of the Reports of Lieutenant WYSE of both seasons, I have the belief that the closing paragraph of my last paper is verified, namely: "That no possible route exists comparable with what had been presented in the surveys made by order of our Government."

The able reports of Commander E. P. LULL and Civil Engineer A. G. MENOCAL, U. S. Navy, on the Nicaragua route, are sufficiently full for examination and criticism by the civil engineer or the expert. There has been given, throughout, a careful consideration to that most important, indeed it may be called vital, question in the construction of an inter-oceanic ship canal in that region—an ample and studied provision to prevent any considerable quantity of surface drainage entering the canal, and the feasibility of accomplishing this object on the located route, as compared with other routes, is, in my belief, a most important point in its favor.

The most important physical feature is the existence of Lake Nicaragua, which, when full, is 107.6 feet above the ocean levels. This is designed to be the summit level of the canal. The lake has a superfice of 2,800 miles, with a surface drainage falling into it, roughly estimated at 9,450 miles, which furnish an outflow of water by the San Juan River twenty times as great as the commerce of the world could require in the lockage of vessels passing through the canal.

Even this super-abundant water supply without the cost of a feeder is not the most beneficent feature; it is in the equalization of floods from so large a superfice, so that in reality the surface level of the lake may be said to change almost imperceptibly from day to day. In this lies the practicability of utilizing the upper part of the San Juan River for slack water navigation. The river itself favors this, by reason of its singularly small water-shed, other than that of and through the lake. On the one side it is flanked by the Rio Frio, which runs in almost the opposite direction, and empties its waters into the lake, and on the other, by a very narrow water-shed above the mouth of the San Carlos, below which it is not designed to use the bed of the stream.

The River San Carlos, flowing from the mountains of Costa Rica, has the general features of inter-tropical mountain streams, and, in striking contrast to the River San Juan in periods of floods, throws "back water" far above the Machuca Falls, 16 miles above, on the San Juan River. Below the mouth of the River San Carlos, from its floods and the vast quantity of debris transported by it, the utilization of the bed of the San Juan River, for slack water navigation, would be hopelessly impossible. This river, forming so marked a contrast to the San Juan, seems a reminder of the impracticability of utilizing the bed of any stream, other than the San Juan, in that region, for slack water navigation, or indeed of constructing a "thorough cut," by which is meant an Inter-oceanic Canal without locks. A canal so made must be the ultimate drainage of all the adjacent water-sheds, and must receive the debris of the mountain torrents, amounting, in the aggregate, to incalculable thousands of tons yearly.

A verification of the necessity of guarding against surface drainage falling into a canal, is given on page 1 of the Bulletin Décadaire of the Suez Canal, of June 12th, 1878. In summing up expenditures for repairs is the following :

"On the part of the canal in the vicinity of Suez, on the 25th of "October last, a violent storm produced a sudden and immense "temporary torrent, which, precipitating itself from the mountain "of Attaka, fell into the canal, carrying with it a very large mass "of solid material ; this deposit, thanks to the activity of our "employés, was dredged very rapidly, so that the navigation was "not retarded a single day, but this unexpected dredging has added "30,000 francs to the expenses of the canal."

The mean annual rain-fall at Cairo, less than 100 miles from this locality, is one and three-tenths of an inch. At Aspinwall, the mean annual rain-fall is 124.25 inches ; during the month of November, 1870, there was a rain-fall of 32.5 inches, twenty-five times the mean annual rain-fall at Cairo. If the rain-fall, as at Aspinwall, were the normal condition along the line of the Suez Canal, it seems altogether probable, from the damage and expenses caused by one shower, as quoted above, it would be a matter for serious consideration, whether it would not be an economy to lock up sufficiently high, at least, to avoid the effects of the surface

drainage. Then, if to the debris of a country denuded of wood, were added the trunks, roots, and limbs of trees, it would be a still more serious difficulty to get rid of them also, even in the region of the Suez Canal, one of small water-sheds and easy slopes, as compared with any part of inter-tropical America.

Referring again to the line of the Nicaragua Canal, at and above the mouth of the River San Carlos, it leaves the bed of the San Juan River on its left bank, and follows along the general course of the river for a distance of 28.1 miles. The plans provide ample culverts to discharge the heavy floods from the adjacent hills, with their debris, into the San Juan River, which bears it along until it reaches a point approximating to the ocean level, where the dynamic force is sufficiently weakened to allow it to rest. A failure to provide sufficiently for the surface drainage, in a country subject to heavy rain-falls, and withal of steep escarpments, would lead eventually either to the abandonment of the navigation of the canal, or to a vastly increased expenditure, to effect what could have been done at far less cost in the construction of the work.

At the distance of 28.1 miles below the mouth of the San Carlos River, the canal, as projected, takes a direct line to Greytown, a distance of 14 miles, passing through deep cuts, that it is now known can be avoided with a considerable decrease in the estimate for labor. When the location of the canal was made, the season was so far advanced that it did not allow the necessary examination to be made to improve this part of the canal line as located. Civil Engineer A. G. MENOCAL, U. S. Navy, has since made a sufficient examination to assure him of a more favorable location, with a probable decrease of the estimate for construction of $3,000,000.

A summary of distances and estimates of cost as given in the Report of Civil Engineer MENOCAL is as follows :

Western Division.—From Port Brito to the Lake. Distance, 16.33 miles ; estimated cost	$21,680,777.00
Middle Division.—Lake Nicaragua. Distance, 56.50 miles ; estimated cost . .	715,658.00
Eastern Division.—From Lake to Grey-	

town. Distance, 108.43 miles; estimated cost	25,020,914.00
Construction of Greytown Harbor . .	2,822,630.00
" " Brito " . .	2,337,739.00
Total. Distance, 181.26 miles; cost, .	$52,577,718.00

The expert who will carefully examine the items and estimated cost as shown by the Report and plans, will assure himself that the object was to present fairly and in detail, all of the work required, and at a fair estimate of cost.

It cannot be denied, however, that the estimates of cost and actual cost of construction have diverged so widely in very many great works, and notably with the Suez Canal, which had no uncertain element in construction except the drifting of the loose sands of the desert, that it would be a grave error not to recognize this fact. Had such been the case with the Suez Canal, and ample provision been made to carry on the work continuously, it is fair to presume that in the time gained for transit of vessels and consequent income, and the avoidance of the payment of interest on dormant capital, the actual cost of the canal might have been one-third of what the stock and obligations now represent.

A true economy, therefore, will be to consider the cost of the canal, including the interest on dormant capital, as double of the estimated cost of construction, in round numbers at $100,000,000.

The actual line of the transit, 181.3 miles, is far greater than the distances demanding labor; thus, to enable the lake to be navigated 56.5 miles, involves labor only on a few thousand yards at the inconsiderable cost of less than three quarters of a million of dollars, and the river navigation, by slack water, 63.02 miles, only $8,679,253, which includes four dams, three locks, three short canals around the dams, the diversion of the mouth of the San Carlos, and the necessary blasting and dredging, in short, the total cost over the distance named. Thus, actually 119.5 miles of transit is represented by an estimate of $9,394,911, nearly $1,000,000 less than the estimated cost of the feeder and its adjuncts of a canal *via* the Isthmus of Panama. The cost of the work falls really on the 58.23 miles requiring construction, the construction of seventeen lift-locks other than the three above named, and one tide-lock, and the construction of two harbors.

No less than twelve miles of the 58.23 referred to above, as entailing the heavy part of the expense, are so situated as to allow the work to be done by machine labor. Between Greytown and the point where the projected line of the Canal strikes the San Juan River, there is a large extent of alluvium, there being, in fact, several ridges of hard ground very favorably situated for the construction of locks, requiring but little cost for foundations.

The line of Canal being accurately marked, a rough tramway may be constructed on each bank, with foundations made of the felled trees and their roots, capable of sustaining and carrying along heavy derricks, and steam-power to fell, cut up, lift and deposit, first the trunks and limbs, and then pull out and put in place the stumps of trees, in the best manner to strengthen the embankments. Dredging machines can then follow, cutting their own channel, and deposit at once the soil to form the embankments. Should trunks of trees be found embedded, our Red River and other similar experience will enable the work still to proceed without material delay or a very large increase in cost of labor.

This mode of procedure could be practised also over nearly two miles on the west coast, leaving only about fourteen and a half miles on that section where the plow, scraper and pickaxe would have to do the work.

The Government of Nicaragua is now engaged in blasting and removing rock from the channel of the San Juan River to improve its navigation for small vessels, employing the methods and appliances of Civil Engineer MENOCAL at a cost not exceeding two dollars and a half per cubic yard, which is one half of the estimate made by him for that work ; as the depth increases, doubtless the cost of excavation will also, but certainly not beyond the estimate on that part of the projected canal.

In relation to the formation of the harbors :—The Dutch as a people have done so much in constructing dykes and harbors, that their processes may be carefully considered if not adopted. Bamboos of large growth in any quantity are close at hand, which from their length and toughness may be an admirable substitute for small wood growths, so far as mattrasses are concerned. Abundant stone, sand, and a superior lime are near at hand on the San Juan, permitting a free choice of material in the formation of the harbor.

There is a well established fact which I shall mention, as it seems to have a practical relation in connection with contours or facings of artificial harbors. This fact was observed by the late Rear-Admiral Davis and Professor De Sor, on Cape Cod, where the flood tide "divides," one part setting north, the other south: *the debris* of a vessel wrecked, *were invariably found in the direction the flood tide set;* also, it was found that when coal vessels were wrecked on the south side of Nantucket Island, the coal was transported east, and then north, and deposited inside the hook at Great Point, this being too the course of the flood tide.

There is no engineering difficulty in the construction of this work; with the exception of the uncertainty as to cost of the harbors, and the probability of finding buried trees in the excavation of the alluvium, there seems to be no likelihood of contingencies arising which would materially increase the cost of the construction above the estimates on any part of the projected line of the inter-oceanic ship canal. I shall have occasion, on referring to other proposed routes, to point out a marked difference in this respect.

The surveys and location of the Panama route for an inter-oceanic ship canal were also made by Com. E. P. Lull, assisted by Civil Engineer A. G. Menocal, U. S. N., and a sufficient number of young navy officers to carry on the work vigorously, which was begun in January, 1875. An actual location was made along its entire length, and calculations also of approximate cost on a common basis with those made of the Nicaragua route by the same officers. The estimates and all information published appear in the appendix to the Report of the Secretary of the Navy, in 1875; the plans, etc., were made as fully as those of the Nicaragua survey, but owing to a failure of an appropriation by Congress for that purpose, have not been published.

The length of canalization required is 41.7 miles; a viaduct is necessary over the Chagres River, of 1,900 feet in length, the surface-water in which would form the summit level 123.75 feet above the mean (half) tides of the oceans. Twelve lift-locks on each side and one tide-lock on the Pacific side are required, twenty-five in all, being four in excess of the Nicaragua route. A feeder and adjuncts are required at an estimated cost of $10,366,959, which, as before stated, is $972,048 greater than the estimated cost of the whole distance

improved and not canalized on the Nicaragua route, a distance of one hundred and nineteen and a half miles. In this connection it will be remembered that the Nicaragua route requires no feeder.

The total estimated cost of the canal by the Isthmus of Panama is $94,511,360, in round numbers double that of Nicaragua.

The level of the highest water-mark apparent at the point proposed for the construction of the viaduct was found to be seventy-eight feet above mean (half) tide. As the ordinary elevation of water at the same point is only forty-two feet above the same level, this great rise, thirty-six feet, known to have taken place in six or eight hours, would cause serious apprehension at times for the safety of the viaduct.

The water supply that year, 1875, was supposed to be ample, and it was stated that the water was unusually low. In the month of April of this year, Civil Engineer MENOCAL, from personal observation of the Chagres River, regarded the water supply as inadequate; the volume of water was in fact reduced at that time to a mere rivulet. This deficiency of water may be regarded as of rare occurrence, and at a fixed period of the year, and could be ameliorated, if not obviated by the construction of extensive, and no doubt expensive, reservoirs on the upper waters of the Chagres.

The most serious defect of this route is shown in the report of Commander LULL, as follows: "Large vessels, of eighteen feet "draught and over, of which, as I believe, there will be very few "in the future, would have to wait for a favorable stage of the "tide, to enter or leave the canal, making a delay, in extreme cases, "of from five to six hours. The enormous cost of giving a deeper "channel we regard as a worse evil than any small delays to ships "in passing."

Commander LULL sums up the advantages and disadvantages of the Panama route as follows: "The advantages of this line are: "an ample water supply; an open cut, with but a moderate "depth of excavation; a comparatively short distance from sea to "sea; fair harbors on either side; the proximity of a well-con-"structed railroad; the established communication with the princi-"pal ports of the world; the absence of high winds; and, in com-"mon with the whole Isthmus, the fertility of the soil and the "salubrity of its climate during the dry season.

"The disadvantages are: the large annual rain-fall; the want of "material for construction purposes; the character of some of the "swamp lands in certain periods of the line; the amount of tunnel- "ing required in the feeder; the necessity of a viaduct; the pre- "vailing calms of Panama Bay, causing tedious delays to sailing "vessels; and, finally, as compared with more northern lines, the "greater distance of Panama from the west coast of the United "States."

The want of material for construction purposes enumerated among the disadvantages, would lead to heavy expenditures in cost and transportation, as compared with the Nicaragua route, where abundant material of all kinds is found convenient to, if not on the projected line. Owing to the great prevalence of rain and the lack of material at hand, it is probable that the actual cost of construction would exceed fifty per cent. for a given amount of work as compared with the Nicaragua route.

The construction of the Panama Canal as located, requires a "summit cut" of 4.81 miles in length and an average depth of cutting of 76 feet above the proposed water-surface of the canal, which would make a cut of 102 feet necessary to ensure the passage of vessels of 24 feet draught.

The liability to land-slides in this deep cut would be very great, as is the case along the line of the Panama Railroad, necessitating a slope probably of two to one; and of course, in making the excavations, requiring the considerable expense of removing the material to a place of deposit. With all of these grave disadvantages, it may be admitted that the Panama route should be regarded as practicable, did not a better one exist. It is, at least, far superior in practicability to any line lying south of it.

In relation to other actual locations made for the construction of an inter-oceanic ship canal, what is known as the Atrato-Napipi route was surveyed by Commander T. O. SELFRIDGE, U. S. N. More detailed and specific locations were made throughout its length by Lieut. FREDERICK COLLINS, U. S. N., in 1875.

A careful examination of their reports will reveal very great difficulties to be overcome, and the doubtful results practically attainable, on a common estimate of labor and cost of execution, with what relates to the two routes already summarized, namely, the Nicaragua route and the Panama route.

The reports and location of two routes by Lieut. WYSE, of the French Navy, indicate the existence of the same grave difficulties in exaggerated dimensions that belong to the Atrato-Napipi route. Of the two, he prefers what may be designated the Tuyra-Tupisa-Tiati-Acanti route, which, by the employment of a tunnel, the length of which is still uncertain, is projected as a canal without locks; consequently the sea-level will represent the surface-level of the canal, except the additional elevation due to the surface drainage which the canal must inexorably take.

I will state, briefly, the physical conditions and the methods proposed by Lieut. WYSE to overcome the very many grave difficulties which the projected line of ship canal presents.

The first section of the projected canal consists in deepening the channel-way, where necessary, of the Tuyra River, which falls into the Gulf of San Miguel, and through the improvement of which the river is intended to be made navigable to the commencement of the second section.

The second section is a cut from the Tuyra River, east in direction, to the junction of the Chucunaque and Tupisa Rivers. This cut is intended to take the entire discharge of those two rivers, whose water-sheds, as far as can be ascertained from the maps, is approximately 1,200 marine miles. Taking the estimated amount of excavation and length given, 16,200 metres (10.06 miles), gives a cross section of 705 metres as the mean, and the capacity to discharge, *with full banks,* the waters of the Chucunaque and Tupisa Rivers. It will be shown, hereafter, how inadequate this prism would be to this discharge, with a velocity of water that would admit of navigation, during the period of floods at least, which is more than half of the year. In the absence of more specific information as to the volume of water in periods of floods of the Chucunaque, a quotation is made from page 135 of the Report of Commander SELFRIDGE: "At one place, where the banks are about twenty " feet high, we noticed large trees, thirty inches in diameter, lodged " at least thirty feet above the ground, showing the great power and " extent of the floods during the rainy season."

The point at which this observation was made is on the Chucunaque, some twenty or twenty-five miles in a direct line above the mouth of the Tupisa, at which point the canal crosses the mouth of

the Chucunaque. It is proposed across the mouth of the last named river to erect a strong grillage, supported by abutments of masonry, to protect the canal from the floating debris. It is stated that this device will permit the waters to flow, and will arrest the trees, &c. It seems to me that the strong grillage would inevitably form a dam through the lodgment of driftwood, and bank up the waters sufficiently either to cut channels around the grillage, or, if restrained sufficiently, that the waters would reach such a height as to carry away whatever opposed their free flow.

There are other grave difficulties in the proposed treatment of the second section which will be apparent to any one who will examine the reports referred to. I will confine myself to expressing dissent to the supposition that the debris brought down by the Chucunaque need give no concern, as the strong tides would bear it away and deposit it where it would do no harm. Yet the reader of the report will remark that dredging the bed of the river to a considerable extent on the first section is a part of the plan. In general, engineers will agree in the entire probability that dredging the bed of a running stream may be regarded as simply increasing the depth temporarily, and no longer in fact than the recurrence of floods such as formed the original deposit.

The third section is 11,400 metres (7.08 miles) in length. The projected work is to cut off the sinuosities of the Tupisa River, and deepen it sufficiently below the ocean level to secure the passage of vessels of great draught. This is supposed to involve no difficulty; whatever obstacle is presumed to exist from the discharge of debris from ravines, is to be met by the excavation of pockets at their mouths, and through the construction of grillages to protect the canal from drift-wood.

The total amount of material to be excavated and removed is stated to be 9,760,000 cubic metres, 500,000 of which is supposed to be rock. This mass is to be excavated and *transported somewhere*—a most difficult matter in the execution of the work, when it is remembered that it includes excavating and removing half a million metres of rock below the sea level.

The fourth section, as projected, leaves the bed of the Tupisa River and extends to the entrance of the projected tunnel; it is 17,000 metres in length (10.56 miles), and has a mean depth of

excavation of 33 metres (108,26 feet), including the part designed to be below the surface level of the ocean. It is stated, that the upper layer is vegetable detritus two or three metres thick, then a layer of six or seven metres of clay, overlying rock, easily excavated with the pickaxe to a mean depth of 23 metres (90.5 feet). It is assumed that this rock can be excavated and removed at $1.20 per cubic metre; this sum is one-fifth the amount estimated for rock excavation in the bed of the San Juan River, in Nicaragua, where no difficulty exists in depositing the material when excavated. It is obvious that all of this material, composed of vegetable mold, clay and rock, has either to be hauled up and placed far back of the escarpment, to prevent its washing in again, as much as possible; or it has to be removed on the sections of the canal previously constructed, through the section from the point of excavation, and through the completed section, a mean distance of twelve miles; and even then, no dumping-ground exists nearer than the ocean, without at least rehandling the whole mass.

Page 95 of the first report states, that the bottom of the canal in sections 2, 3 and 4 will form an inclined plane equal to 4.75 inches to the statute mile. This inclined plane would, it is stated, make the tide from the Pacific almost nominal at the western end of the tunnel. Taking the distance from the beginning of the second section to the end of the fourth, and the proposed rise, and adding thereto the same incline from the head of Darien Harbor for the corresponding distance per chart, would make the total rise of the bottom five and six-tenths metres (18.37 feet); with this grade there seems to be no reason why the spring tides should not continue on through the tunnel into the Atlantic.

No depth of water is given for sections 3 and 4, but certainly it is designed that it shall be sufficient to float a vessel of heavy draught at full tide at least. If the tide is to cease at the entrance of the tunnel, it would seem that this could only be effected by a tide-lock (which is not proposed), or by increasing the incline or grade so that the bottom of the canal at the entrance to the tunnel would cut the plane of the high water at that point, or that the water in the canal below should be sufficiently shoal to retard the flow of the tide, in which cases, whether sufficient or insufficient for vessels to pass, the

surface drainage would represent the actual depth of the canal at this point at full tide.

The extreme tides at Chepigana are given by Commander SELFRIDGE at about 24 feet, and by Lieut. WYSE at about 25 feet, with a very considerable difference in the height of the neap tides. These differences in height would be necessarily continuous above, as far as the deepened and straightened channel permitted, and the deepening and straightening of the channels of these streams sufficiently to permit navigation would certainly enable the tide to have a free flow.

The inclined plane of the excavation as proposed—4.75 inches per statute mile—would give the width and depth necessary for a ship canal, a current of not less than 2.2 miles per hour. The tidal action under normal conditions of water-flow would increase this current greatly, and when floods would occur we may well suppose that in earth excavations the scouring effect would be very great, destroying in a great degree the excavated grade, and depositing the material where it may or may not obstruct or entirely bar the passage through the canal to vessels of heavy draught.

This ship canal, as projected, presents the remarkable condition of inviting and receiving the surface drainage, without the interposition of feeders, being itself the waste weir for a large superfice of mountainous country subject to extraordinary rain-falls. Imagine the effect on this canal-bed when a sudden rain-fall of six or eight inches would make these mountain ravines actually roaring rivers, which in the dry season, owing to the rapid fall, are almost without running water.*

This method of location imposes the extraordinary and onerous condition of *having no natural dumping ground* for enormous masses, such as the excavations proposed. The canal itself being the lowest level short of the depths of the ocean, renders it necessary either to rehandle the whole mass, or to transport the

* In Washington, June 10th, 1876, there was a rain-fall of 2.03 inches in one hour. July 30th, of the same year, there was a rain-fall of 4.12 inches in eight hours and a half. In October of this year there was a rain-fall of 4.44 inches in twelve and a half hours, nearly all of which fell in nine and a half hours. The mean annual rain-fall is 41.54 inches. In 1877, it was 52.59 inches. At Aspinwall mean annual rain-fall 124.44 inches, in 1872, 170.16 inches.

material to the ocean. In short, to make the excavation is a small part of the integral of cost, the transportation of the material being in fact the most expense.

The fifth section is a projected tunnel 36 metres high (118.1 feet), of which 10 metres (32.8 feet) are below the sea level, 16 metres (52.49 feet) wide at the bottom, and 20 metres (65.6 feet) at the surface or ordinary, or rather *intended water level*, and of still an uncertain length at the time of the publication of the second report. The shorter length named is 9,300 metres (5.78 miles), and the longer 18,500 metres (11.49 miles), almost double the first distance.

How this tunnel is to be excavated and walled ten metres (32.8 feet) below the sea-level is not stated; if not excavated and walled in water, it must be kept free from water by means of pumps. It is safe to say that the enginery of the world could not be placed to effect this object, during the construction of the work. The whole region tunneled through has a mean elevation of hundreds of feet, and peaks of more than two thousand. Beyond a doubt, a line of tunnel excavated 32.8 feet below the ocean level, would uncover sources of water of great power, sufficient to wash out whatever was within the tunnel as far as excavated.*

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* The excavation of St. Gothard tunnel, now in progress, is the most recent development and illustration of what may be done in overcoming difficulties. The following information is from Johnson's Cyclopædia:

Length of tunnel, 14,900 metres; terminations Airolo and Göschenen, respectively 1,145 and 1,105 metres above the sea level. The centre of the tunnel is to be 1,154.4 metres above sea-level, *making a grade of one metre to the thousand* towards Airolo to get rid of the water; the other grade is 5.82 to the thousand.

On the high Alps the rain precipitation is small, as compared with the Isthmus, yet with a grade of 1-1000 for drainage. "The work has been fre-" quently impeded by the caving in of the rock, and by the irruption of the " water from fissures in the strata." Imagine the increased impediment were the bottom of the tunnel 32.8 feet below the surface level of the ocean.

On page 206 of the Report of the Secretary of the Navy for 1875, will be found the instructions to Commander LULL, in relation to the examination for tunneling between the Chepo River and the harbor of San Blas. Page 221 gives the deductions of Commander LULL, and a rough estimate of cost of tunnel.

This route would, in fact, require inconsiderable labor or difficulty EXCEPT THE TUNNEL, which would be, in length, little more than one-half that of the

In the opinion of the ablest engineers to whom I have presented the question, it is impossible to make an approximate estimate of the cost of tunnel, as conditioned by Lieutenant WYSE, of the time necessary for its completion, or to state satisfactorily any known methods which could ensure the execution of the work.

The sixth section involves a length of 10,000 metres (6.21 miles), and a depth of cutting of 25 metres (83.33 feet), including an intended depth of 8.7 metres (28.54 feet) below the sea-level.

At this end of the canal it is proposed to construct a harbor, which would not be less expensive than the one proposed at Brito, on the Nicaragua route.

Let us conceive that this stupendous work, from ocean to ocean, is completed, tunnel and all, as proposed. As shown by data, a rain-fall of six inches, in as many hours, is not at all unusual in that region. Obviously, from the shorter distance to the sea, the readiest escape of the waters of the Tupisa Valley would be through the tunnel. We can form some idea of the relative size of its water-shed, with steep escarpments to its excavated bed; and also of the dimensions of the cross section of the tunnel, which is the continuation of the artificial channel of the Tupisa towards the Atlantic.

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greater length named as possible by Lieutenant WYSE, on his [projected route.

A tunnel between the Chepo and San Blas harbor could be constructed to free itself from water and have, probably, a sufficient water supply from the Chepo, rendering lockage necessary only sufficiently high to give drainage for the construction of the tunnel. Commander LULL says: "The line bears no "comparison to either the Nicaragua route or that of Panama as developed."

A distinguished officer of the engineer corps of our army, informs me that the *head room* of the tunnel, as proposed (85.3 feet) would be insufficient; that in a bridge in our country 135 feet was regarded as barely sufficient,

The width at the water line as proposed (65.6 feet) is little more than the actual beam of the class of vessel that would usually be employed, say a beam of fifty feet, one-ninth the length of a vessel of 450 feet. This would leave less than eight feet on each side, provided that the vessel was pointed *absolutely fair*, which would rarely be the case; the slightest deviation, of course, would throw the bow of the vessel on one side and the stern on the other. It was not my intention to object to the size of the tunnel, from the fact that it could not, by any possibility, be constructed as a paying investment, even though it be admitted possible as an effort of the engineer, WITHOUT REFERENCE TO COST. If the tunnel is to be made, then the dimensions should, undoubtedly be increased.

Within an hour or two a perfect deluge would pour down the ravines from a thousand times the superfice of the continuation of the Tupisa channel ; the rush of waters through the tunnel would be terrific, sufficient, probably, to destroy almost the vestige of it.

With the exception of the surveys of Lieutenant WYSE, of the French navy, above alluded to, all of the routes surveyed, indeed, I may say, all of the most practicable routes which exist, have been carefully examined by the Commission appointed by the President of the United States. To satisfy the wishes of the Commission, our Government executed the survey and location of an inter-oceanic ship canal, *via* the Isthmus of Panama. The Commission was composed of the Chief of Bureau of Engineers, U. S. Army ; the Superintendent of the U. S. Coast Survey ; and the Chief of Bureau of Navigation, U. S. Navy. No difference of opinion existed in the Commission, as shown by their Report to the President, which indicated, in a marked degree, their opinion of the superiority of the Nicaragua route over all others. The recent surveys of Lieutenant WYSE have, in fact, served to confirm the justice of the conclusions of the Commission.

The question then at issue is, can an inter-oceanic canal be constructed with advantage to its constructors, as well as to the advantage of the commerce of the world? The points between which the trade would naturally pass through the canal are shown by the map.

1st. Between the Atlantic coasts of Europe and America and the Pacific coasts of this continent.

2d. Between the Atlantic coasts of Europe and America and Japan, Northern China, the Philippine and Sandwich Islands in the northern hemisphere, and the eastern coast of Australia, New Zealand, and numerous productive islands in the southern hemisphere.

The Chief of Bureau of Statistics has kindly furnished me with several Tables, two of which relate to the tonnage of the trade that would naturally pass through this canal if constructed. Additional information from the same source and from Owen M. Long, Esq., U. S. Consul at Panama ; also from Mr. P. M. McKellar, U. S. Vice-Consul at Valparaiso, indicate that not less than 3,000,000 of

tonnage, British and our own, would pass through the canal yearly, and that the aggregate of the other commercial powers would be very large. I have to regret that my statistical information was received too late to collate it properly; its publication otherwise would simply lead to confusion. A glance, however, at the points between which the trade would pass through the canal, cannot fail to be as satisfactory and convincing as the most elaborate and accurate tables.

TABLE A.

Tonnage entered at Ports of the United Kingdom from the following countries during the calendar year 1877 [*from the annual statement of the Navigation and Shipping of the United Kingdom*].

COUNTRIES.	TONS.
Central America (east and west coasts not distinguished)	10,113
Mexico	59,054
West Coast of the United States	351,142
Islands in the Pacific, exclusive of Figi and Australasia	4,886
Japan	11,678
China, exclusive of Hong-Kong	150,222
Hong-Kong	24,907
Peru	215,438
Bolivia	21,932
Chili	52,539
Philippine and Ladrone Islands	56,194
Total	958,105

Bureau of Statistics,
Oct. 24, 1878.

JOSEPH NIMMO, JR.
Chief of Bureau.

TABLE B.

Statement Showing the Tonnage both of American and Foreign Vessels entered at Atlantic Seaports of the United States, from China, Japan, the Hawaiian Islands and the Philippine Islands, during the Fiscal Year ended June 30, 1877.

	TONS.
From China	20,103
" Japan	17,776
" Hawaiian Islands	876
" Philippine Islands	60,156
Total	99,911

Bureau of Satistics,
Oct. 21, 1878.

JOSEPH NIMMO, JR.,
Chief of Bureau.

TABLE C.

Table of distances between certain Ports via Cape Horn, and via Nicaragua Canal.

	DISTANCES VIA CAPE HORN.	VIA CANAL.	DIFFERENCE.
New York to Valparaiso	8,720	4,626	4,094
Liverpool " "	9,100	7,326	1,774
New York to Callao	10,000	3,376	6,644
Liverpool " "	10,400	6,026	4,374
New York to Honolulu	13,530	6,550	6,980
Liverpool " "	13,780	9,200	4,580
New York to San Francisco	13,610	5,010	8,600
Liverpool " "	13,665	7,600	6,065
New York to Yokohama	16,700	9,900	6,800
New York to Shanghai	14,500	10,300	4,200
New York to Hong-Kong	17,420	11,550	5,870

I will not dilate upon the saving of distances shown by appended Table, and other information contained in the admirable pamphlet of Professor J. E. Nourse, U. S. N., published in 1869. Its title is "The Maritime Canal of Suez, and comparison of its probable re-"sults with a Ship Canal across this Continent." I commend it to

all who feel an interest in this great question. An illustration may be given of the saving of distance from this port to San Francisco. Via Lake Nicaragua it is 5,010 miles, and through the straits of Magellan 13,610—a saving of distance of 8,600 miles.

A point worthy of mention is, that were it possible to use this canal between Atlantic ports and those of the Pacific without decreasing the distance of the voyage, the advantage of its construction would still be apparent, and would be appreciated by all intelligent navigators on account of the favorable winds that would be thereby obtained, on both outward and homeward voyages, through making very slight detours to effect that purpose, the canal route taking the place of the tempestuous seas of Cape Horn and its vicinity, and in their stead giving trade winds in the region of the tropics, and westerly winds and good weather usually, in the higher latitudes adjacent to that region.

A work of such magnitude as this inter-oceanic ship canal, so distant from the money centres of the world, requiring a considerable time to complete it, even if prosecuted in the most vigorous manner, and intended to serve world-wide interests, could without doubt best be constructed on an international basis. The United States is relatively near the work, and has a two-fold interest—the one to unite her coasts by convenient water transportation, the other of external commerce for both coasts, and especially to secure to the west coast a European market for its average crop of 20,000,000 sacks of wheat.

The great commercial nations may fail for a time to recognize the full importance of executing this great work, or the means that will best forward it, but sooner or later, probably in the near future, the inter-oceanic ship canal *via* Lake Nicaragua will no longer be a problem, but an accomplished fact.

The construction of this work on an international basis, would mark an era in the world's progress; it would, in a remarkable degree, facilitate the commerce of the world between the most distant points, leaving it impossible thereafter to make any work which would compare with it in practical results.

Its construction internationally would be "a sign and token"; it would show that modern diplomacy appreciated the possibility of *obtaining mutual and common advantages*, and had discarded the fallacy of old that diplomacy was intended for and only useful in

what might be truly called "sharp practice." Peoples have arrived at that intelligence that the Government of a nation may, in its relation to another, rather seek *to discover and promote common interests* than hope to obtain and maintain mean advantages.

In this intelligent view the Government and people of Nicaragua have hitherto endeavored to bring about the construction of the inter-oceanic ship canal, offering to our Government some time ago ample powers and concessions to construct it, with faculties based on the broad and common interests of the world's commerce.*

This enlightened and liberal offer was not responded to at once, probably because it was deemed proper in advance to ask the views and co-operation of such powers as might feel disposed to participate actively in the construction of the canal. It is believed that all of the great commercial nations have been invited by our Government to consider the subject, and to express fully and frankly their views in relation to the most advantageous manner of bringing about the construction of the work.

In my paper, read two years ago, I endeavored to show that our trans-continental railroad interests would doubtless be promoted through the construction of an inter-oceanic ship canal, and also, as a whole, that it would probably be advantageous to the Suez Canal, forming as it would a supplementary chain for voyages around the world, in regions of good weather and aided by fair winds. I have reason to believe that this same opinion is entertained by those interested in that great work.

It seems pertinent on this occasion to acknowledge, that to the courage, devotion and ability of cultured officers as leaders, to Lieutenant WYSE, of the French Navy, and to Commodore SHUFELDT, Commanders SELFRIDGE and LULL, and Lieutenant COLLINS, of our Navy, and to their able assistants and followers, we are indebted for so much positive, substantial information, sufficient in fact to a full appreciation of what can and what cannot be accomplished. It is impossible for any one having no personal knowledge of the Isthmus to appreciate the difficulty of making surveys in that

* It is proper to state that the same views were entertained by Mr. Peralta, the learned and excellent Minister from the Government of Costa Rica, whose territory is contiguous, and form a part of, the boundary with Nicaragua, along the San Juan River.

region. It is not in the power of man to make physical conditions; all that he can hope to do is to recognize them, weigh them properly, profit by them if possible to do so, and let them alone if they do not afford an advantage. It was in this spirit that the recent United States surveys on the Isthmus have been prosecuted, and their official description made.

In the scope of a reading I have found it only possible to indicate the sources from whence information could be obtained. I shall furnish tables bearing upon the subject, and give to the Society the results of my personal conclusions, and as far as possible, the reasons therefor.

I beg to return thanks to our Chief of Bureau of Statistics, Joseph Nimmo, Esq., to Owen M. Long, Esq., U. S. Consul at Panama, and to Mr. P. M. McEller, Vice-Consul at Valparaiso, for their valuable assistance, and to this audience for their kind and patient hearing of what I have had to say, far short, I feel sure, of what this great subject would permit.


GULF OF CAMPECHE OR MEXICO
YUCATAN
MEXICO
GUATEMALA
HONDURAS
BAY OF HONDURAS
BELIZE
SALVADOR
GULF OF TEHUANTEPEC
PACIFIC OCEAN
L. Terminos
L. Peten
Palenque
Chiapa
Ciudad Real
Soloma
Coban or La Paz
Quesaltenango
Totonicapan
Solola
Rabinal
Chiquimula
Guatemala
S. Salvador
Gracias
Comayagua
Tegucigalpa
Truxillo
Omoa
S. Tomas
Belize
Ambergris Cay
Ruatan I.
C. Honduras
Yoro
Poyas
Jutigalpa
Matagalpa
Choluteca
Chinandega
Leon
Managua
Granada
Nicaragua
Brito
Port S. Juan del Sur
Salinas B.
Port Culebra
C. Blanco
Gulf of Nicoya
L. Nicaragua
Port Realejo
Bay of Fonseca or Conchagua
Port Libertad
Acajutla or Sonsonate
Istapa
Socomusco
Tonala
Tehuantepec
Ventosa
Coatzacoalcos
R. Tabasco
R. Usumasinta
R. S. Pedro
R. de la Pasion
R. Machaquilla
R. Motagua
R. Lempa
R. Ulua
R. Samala
R. Tamarinda
Longitude West from Greenwich
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MAP OF THE
ISTHMUS OF CENTRAL AMERICA
To illustrate the Paper by
REAR ADMIRAL D. AMMEN U.S.N.
1878.
Geographical Miles
English Miles
Routes.
(I) Tehuantepec
(II) Nicaragua
(III) Panama
(IV) San Blas
(V) Caledonia Bay
(VI) Atrato & Tuyra
(VII) Atrato Cacarica & Tuyra
(VIII) Truando R.
(IX) Atrato to Cupica Bay
(X) Atrato to Chiri Chiri Bay
ATLANTIC
OCEAN
HONDURAS
MOSQUITO COAST
NICARAGUA
COSTA RICA
L. NICARAGUA
BAY OF PANAMA
Longitude West from Greenwich